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(56) Documents Cited

US 4274059 A

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UK CL (Edition P) H3W WUL WVP

INT CL⁶ H03F 1/32 3/30

ONLINE:WPI

(54) Abstract Title

Amplifier with means for eliminating crossover distortion and integrator therefor

(57) An audio amplifier has two transistors TR1 and TR2 in series between positive and negative supply rails. A current compensation circuit 10 is connected between the positive supply rail and the emitter of transistor TR2, and is arranged to supply current to the emitter of transistor T2. The current compensation circuit 10 includes an amplifier 12 which is arranged to sense the voltage drop across a first emitter resistor RE1, and control a current generator 14 in dependence upon the measured voltage drop, which is proportional to the current flowing through transistor TR1. Thus, in use, the current compensation circuit 10 acts to increase the current in TR2 by the same proportion as in TR1, in order that TR2 does not become reverse biased. Therefore, the output resistance continues to approximate to RE1 in parallel with RE2, even when the current into the load RL is greater than the quiescent current. In this way, the effects of crossover distortion which are prevalent in Class B amplifiers are greatly reduced.

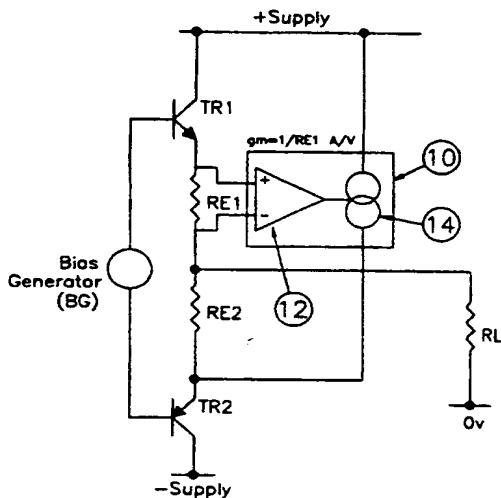


FIG.2

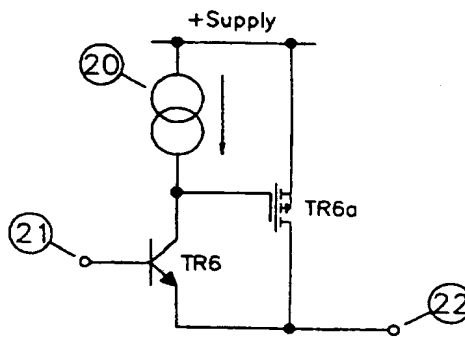


FIG.6

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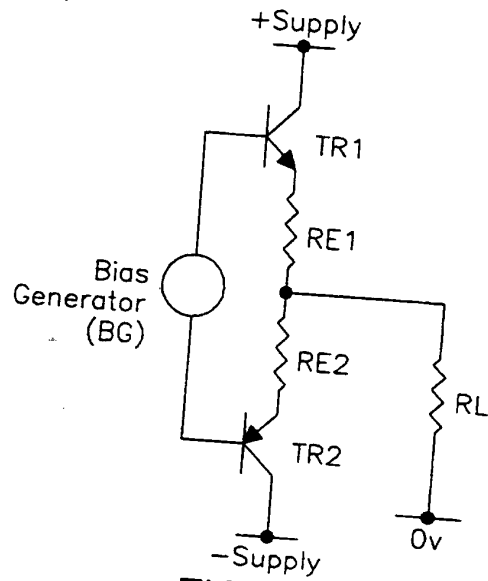


FIG.1

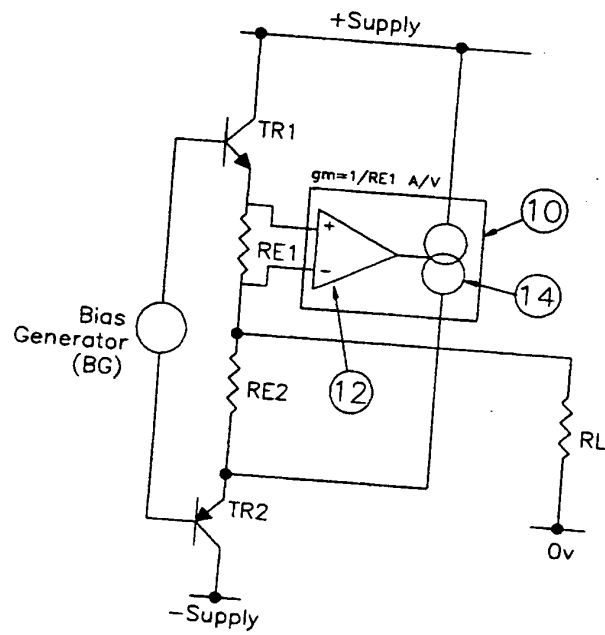


FIG.2

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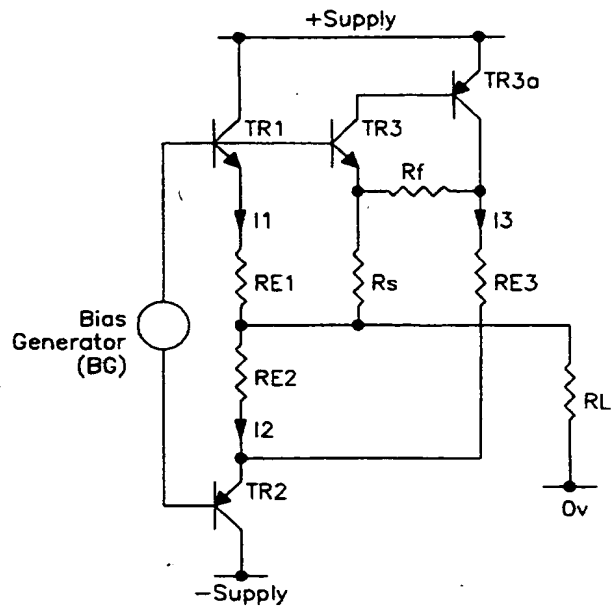


FIG.3

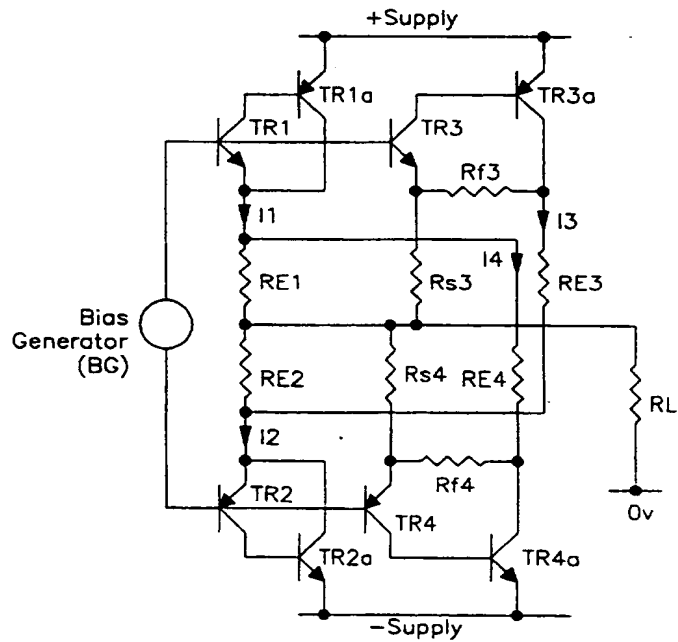


FIG.4

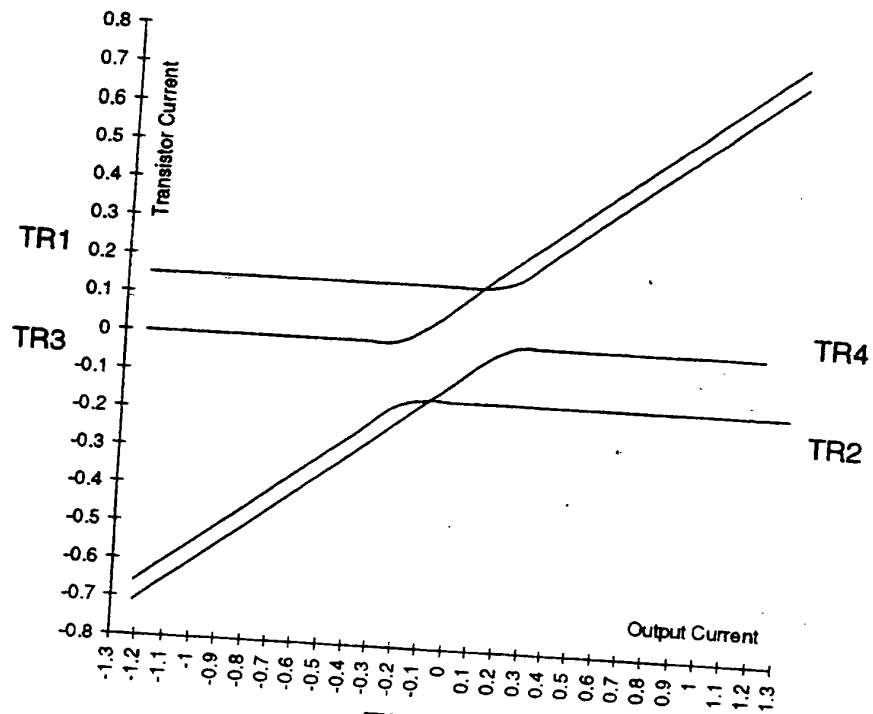


FIG.5

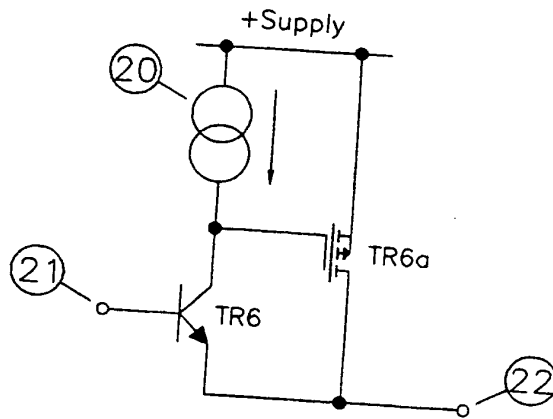


FIG.6

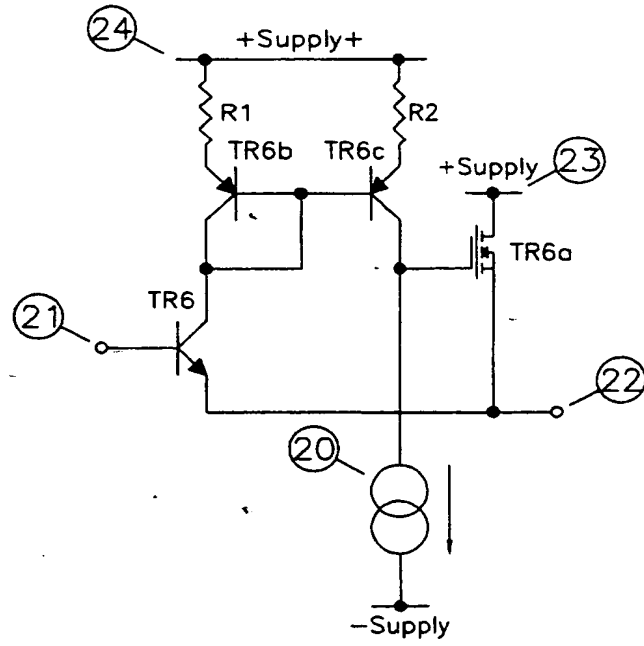


FIG. 7

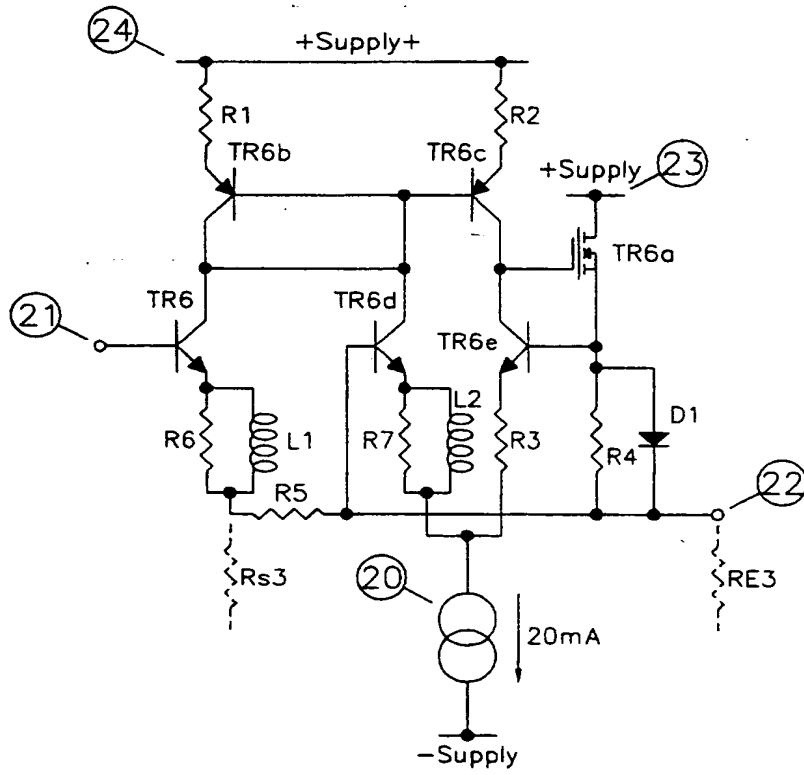


FIG. 8

AMPLIFIERS

This invention relates to amplifiers, and is concerned particularly although not exclusively with audio amplifiers.

Audio amplifiers have traditionally been classified as Class A and Class B amplifiers. Other kinds of audio amplifiers have also been proposed.

Figure 1 of the accompanying diagrammatic drawings shows a simple example of an audio amplifier, comprising a pair of transistors TR1, TR2 connected between positive and negative supply rails, biased by a bias generator BG and having emitter resistors RE1, RE2 connected to a load RL.

In Class A operation, sufficient quiescent current is applied such that both transistors TR1, TR2 are conducting at all times. Under these conditions, the resistance at the emitters of both of the transistors stays low and the output impedance of the output stage is effectively equal to the emitter resistors RE1, RE2 in parallel.

A drawback of Class A operation is that the quiescent current needs to be greater than one-half that of the peak current in either direction into the load. For example, a 100 watt amplifier driving a 4 ohm speaker requires greater than 3.5 amps quiescent current at +/- 30 volts (210 watts).

In Class B operation, the quiescent current is adjusted such that the resistance of the emitter of each of the transistors TR1, TR2 is equivalent to that of its respective emitter resistor RE1, RE2. [The resistance of the emitter of a transistor can be approximated by the equation: $R_e = 0.026 /$

Ie.] While both transistors are conducting, the impedance of the output stage is equivalent to twice the emitter resistors in parallel. But when enough current is being drawn by the load to reverse bias one or other of the transistors, the output impedance becomes equivalent to that of just one of the emitter resistors.

Thus, the Class B amplifier crosses over between two modes of operation. Unfortunately, the transfer function between the two modes is not a linear function, and this leads to crossover distortion. Typically, the quiescent current of a Class B amplifier in a configuration equivalent to the above Class A example of Figure 1 is 100mA (6 watts), a clear advantage in terms of efficiency as compared with Class A.

A variation of Class A and Class B amplifiers is the Class AB amplifier. Here, the quiescent current is set higher than in the Class B example such that, at low volumes, the amplifier operates as Class A, and the output stage does not suffer from crossover distortion. Crossover distortion does still occur, but in two places as the output current passes through twice that of the quiescent. As the volume tends to be higher at this point, in proportion it can be less noticeable.

However, another problem occurs which is known as "gm doubling". In the Class A region of operation, the output impedance of the output stage is equivalent to that of both emitter resistors in parallel, but as the amplifier goes into Class B, the resistance doubles to that of one emitter resistor, as one of the transistors becomes reverse biased. Thus, in the Class A region, the mutual conductance (gm) of the output stage is approximately doubled.

One clear advantage of Class AB is that the setting of the bias voltage is not critical and will not suffer from slight drifts in component values due to ageing or temperature changes.

5 Another design of audio amplifier is known as a "Current Dumping" amplifier. In this rather elegant design by Mr P J Walker, the circuit makes use of feedforward to cancel the non-linearities of output transistors by arranging them inside a bridge. The transistors need no bias but "dump" current into the output via a small coil which is also in the feedback path
10 to a low power current output class A amplifier.

Because the output transistors are not biased there are no adjustments or factory set-up to perform and low quiescent current is obtained.

15 The output impedance in a current dumping amplifier, as in Class B & AB, does change intrinsically with the current through the output devices, and relies on negative feedback to correct for it. Therefore, as in class B, transfer characteristics within the circuit change dynamically including the rate of change of the driver stage and the overall feedback level. This can
20 lead to intermodulation distortion, especially at higher frequencies where reactive components come into play.

Preferred embodiments of the present invention aim to provided
audio amplifiers which may be improved in the foregoing respects.
25 However, the invention is more generally applicable to other kinds of amplifiers.

According to one aspect of the present invention, there is provided an electronic amplifier comprising:

- a. voltage supply rails;
- b. first and second electronic devices each having a respective conduction path and a respective control electrode for controlling conduction in said path, the conduction paths of said first and second electronic devices being connected in series between said voltage supply rails and the control electrodes of said first and second electronic devices being arranged to receive an input signal to be amplified;
- c. an output node disposed between said conduction paths of said electronic devices, for connection to a load to be supplied with output current through said electronic devices; and
- d. first current compensation means arranged to supply current to said conduction path of said second electronic device when current is flowing through said first electronic device under conditions which would otherwise cause current flow through said conduction path of said second electronic device to cease.

An electronic amplifier as above may further comprise second current compensation means arranged to supply current to said conduction path of said first electronic device when current is flowing through said second electronic device under conditions which would otherwise cause current flow through said conduction path of said first electronic device to cease.

Preferably, the or each said current compensation means comprises a further electronic device arranged to sense the current flowing through said first or second electronic device and to supply current to said second or first electronic device in dependence upon the sensed current.

5

Preferably, each said electronic device comprises a transistor.

Preferably, each said electronic device comprises a complementary pair of transistors.

10

Preferably, each said transistor comprises a bipolar transistor.

Each said transistor may comprise a field effect transistor.

15

Each said electronic device may comprise a thermionic valve.

Preferably, the electronic amplifier is an audio amplifier.

An electronic amplifier as above may be an operational amplifier.

20

An electronic amplifier as above is preferably constructed as an integrated circuit.

According to another aspect of the present invention, there is provided an electronic integrator comprising a first bipolar transistor and a current source connected in series, and a high-input-impedance device connected to said first bipolar transistor and current source, to form said integrator.

25

Preferably, said high-input-impedance device comprises a field effect transistor.

5 An electronic integrator as above may further comprise a current mirror connected to said current source.

10 Preferably, said current mirror comprises a second bipolar transistor having its collector-emitter path in series with that of said first bipolar transistor and a third bipolar transistor having its collector-emitter path in series with said current source and its base connected to the base of said second bipolar transistor, the collector-emitter paths of said second and third bipolar transistors being connected to a supply rail of higher potential than that supplying said high-input-impedance device.

15 An electronic integrator as above may further comprise a fourth bipolar transistor having its collector-emitter path connected between the base of the second bipolar transistor and said current source and a fifth bipolar transistor having its collector-emitter path connected in series with that of said third bipolar transistor and said current source.

20

An amplifier as above preferably incorporates an electronic integrator as above.

25 For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 2 is a circuit diagram of a simple audio amplifier, modified to include a current compensation circuit in accordance with a first example of the invention;

5 Figure 3 is a circuit diagram similar to Figure 2, but showing a practical example of the current compensation circuit;

Figure 4 is a circuit diagram similar to Figure 3, but showing a symmetrical arrangement of current compensation circuits; and

10 Figure 5 is a graph illustrating the relationship between transistor current and load current in the example of Figure 4.

15 In the figures, like reference numerals denote like or corresponding parts.

The audio amplifier that is shown in Figure 2 is generally similar to the conventional audio amplifier shown in Figure 1. However, the difference in the amplifier in Figure 2 is the provision of a current compensation circuit 10, connected between the positive supply rail and the emitter of the transistor TR2, and arranged to supply current to the emitter of transistor T2. The current compensation circuit 10 includes an amplifier 12 which is arranged to sense the voltage drop across the first emitter resistor RE1, and control a current generator 14 in dependence upon the measured voltage drop, which is of course proportional to the current flowing through the transistor TR1. Thus, in use, the current compensation circuit 10 acts to increase the current in TR2 by the same proportion as in TR1, in order that TR2 does not become reverse biased. Therefore, the

output resistance continues to approximate to $RE1$ in parallel with $RE2$, even when the current into the load RL is greater than the quiescent current. In this way, the effects of crossover distortion which are prevalent in Class B amplifiers are greatly reduced.

5

A practical example of the current compensation circuit 10 is shown in Figure 3. The current in $RE1$ is measured by transistor $TR3$, the collector of which is connected to the base of transistor $TR3a$. The emitter of transistor $TR3$ is connected to the load RL by a resistor Rs , and to the collector of transistor $TR3a$ by a resistor Rf .

10 While the potential across the load RL is positive, the transistor $TR3$ causes the transistor $TR3a$ to supply current $I3$ to the emitter of transistor $TR2$ via resistor $RE3$. The currents through the transistors $TR1$ and $TR2$ are $I1$ and $I2$ respectively. Using this notation, an analysis of the circuit of Figure 3 is approximately as follows.

15

Assuming Rf and Rs are large compared with $RE1$ and $RE3$ then:

The change in current in $RE3$

$$\Delta I_3 = \frac{\Delta I_1 \cdot R_{E1} * \left(1 + \frac{R_F}{R_S}\right) - \Delta I_2 \cdot R_{E2}}{R_{E3}}$$

20

While both transistors $TR1$ & $TR2$ continue to conduct, any increase in the current in $TR1$ will be accompanied by an equal and opposite decrease in $TR2$. While $R_{E1} = R_{E2}$:

$$\Delta I_2 \cdot R_{E2} = \Delta I_1 \cdot R_{E1}$$

Substituting for $I_2 \cdot R_{E2}$

$$\Delta I_3 = \frac{\Delta I_1 \cdot R_{E1} \left(\frac{R_f}{R_s} \right)}{R_{E3}}$$

$$\therefore \frac{\Delta I_3}{\Delta I_1} \cdot \frac{R_{E3}}{R_{E1}} = \frac{R_f}{R_s}$$

$$\therefore \text{While } \frac{R_{E3}}{R_{E1}} = \frac{R_f}{R_s}, \Delta I_3 = \Delta I_1 = -\Delta I_2$$

5 i.e. The current in TR2 remains constant

When the current into the load RL is negative, transistor TR3 becomes negatively biased and the current in transistor TR2 increases.

10 A similar compensation circuit can be applied to assist the transistor TR1 in a similar way and, in Figure 4, such a symmetrical implementation is shown, using four complementary feedback pairs. Each of the principal transistors T1, T2 is provided with a complementary transistor TR1a, TR2a. A complementary pair of transistors TR4, TR4a current compensates the transistor pair TR1, TR1a, just as the complementary pair TR3, TR3a
15 current compensates the transistor pair TR2, TR2a. The mode of operation of the circuit of Figure 4 will thus be apparent from the preceding

explanation of the circuit of Figure 3. In Figure 4, the output transistors TR1,1a and TR2,2a are current compensated for both positive and negative load currents.

5 Figure 5 is a typical graph of currents in the transistors versus that in the load, where the ratio $RE3/RE1 = 2$. As can be observed, complementary feedback pair transistors TR1,1a and TR2,2a are always forward biased. For clarity, the currents in transistors TR2,2a and TR4,4a are shown as negative. It may be noted that the output current into the
10 load is shared almost equally between the primary output transistors TR1,1a and TR2,2a and the current compensation transistors TR3,3a and TR4,4a.

 The relationship between the ratios $RE3/RE1$ and Rf/Rs can be altered slightly, and the circuit will still continue to operate correctly.
15 However, a better balance between the currents in TR1 and TR3 and the currents in TR2 and TR4 can be obtained.

 A circuit as shown in Figure 4 has been found to work extremely well as an audio amplifier, giving very high performance with imperceptible
20 distortion. However, although the circuit topology was originally developed for audio applications, it could be used in many other kinds of amplifiers, and could also be embodied with other electronic devices such as thermionic valves. Alternative embodiments of the invention may be advantageously applied to integrated circuit amplifiers.

25

 Thus, the embodiments of Figures 2, 3 and 4 may keep the primary output transistors from becoming reverse biased by compensating the emitters with current when typically the load would be driving one of the

transistors out of conduction. Because the compensation is derived from the output current, it is largely independent of load conditions and works with reactive, variable and asymmetric loads. In practice, circuits based on this principle can deliver many times the quiescent current into the load without either of the transistors switching off. For audio amplifiers, Class A performance can be achieved with efficiencies comparable to that of Class B amplifiers.

The above description has, for clarity, assumed the transistors to be near perfect models. In order for the circuit of Figure 4 to work at an optimum, transistor pairs TR3,3a and TR4,4a need to have very high current gain and demonstrate a low output impedance. Similarly, transistor pairs TR1,1a and TR2,2a also need to have a very low impedance at the junctions of RE1,RE4 and RE2,RE3 so that the switching of transistors TR3 and TR4 has minimal effect on the output potential. Described below are the principles of a circuit which demonstrates remarkable transconductance, and improvements to basic topology which enhance the circuit and make it practical for use in amplifiers as described above and in many other applications.

The basic principle on which the circuit operates is shown in Figure 6. A MOSFET device TR6a, which inherently has very high input resistance, is coupled with a bipolar transistor TR6 and a current source 20. Together with the parasitic gate capacitance of the MOSFET TR6a, these elements form an integrator whose error is derived from the potential between the input and output terminals 21,22. The current gain at DC is only limited by the effective resistance at the gate of the MOSFET TR6a, which is largely determined by the quality of the current source 20.

An enhancement to the circuit of Figure 6 is shown in Figure 7. Here the MOSFET TR6a has been rearranged and a current mirror TR6b, TR6c, R1, R2 added such that the gate of TR6a can be driven from an auxiliary supply line 24 with a higher potential than that of the standard supply line 23 which supplies the drain. This means that the saturation voltage of the MOSFET TR6a is reduced, which improves efficiency, particularly in high current applications. The current mirror also has gain (set by the ratio of R1/R2), which means that the current through TR6 can be reduced in proportion to the current source 20, which is chosen to be fairly high to achieve a fast slew rate, otherwise limited by the relatively large gate-source capacitance of the MOSFET TR6a.

Figure 8 shows a further enhancement which provides a major advantage. If TR6 becomes reverse biased, the output device is prevented from switching off by TR6d. As the potential across D1 & R4 decreases below the potential developed across R3 by the current source 20, TR6d starts to conduct and together with TR6e and TR6c forms a long-tailed pair which controls the gate of the MOSFET TR6a, causing a minimum current to flow to the output terminal 22. For example, with $R6 = 18R$, $R4 = 68R$ and the current source 20 set to 20mA, the current in R4, and therefore in the MOSFET TR6a, is maintained at approximately 6 milliamps.

As the MOSFET TR6a is automatically biased at the knee of its operating curve and the integrator is prevented from saturating, optimum switch-on speed is maintained, and crossover energy spikes are reduced to a minimum in amplifier applications, including use as current compensation output transistors of the amplifier principle described above. L1, R6 and

L2,R7 are applied in order to maintain stability at high frequencies, and connected by resistor R5.

5 The circuits of Figures 6, 7 and 8 may be substituted for the transistors 1, 2, 3 and 4 of Figures 2, 3 and 4. For example, using the preferred circuit of Figure 8 in the preferred audio amplifier of Figure 4, the transistors 3,3a of Figure 4 are removed, input terminal 21 of Figure 8 is connected to the base of transistor TR1 in Figure 4, resistor R5 of Figure 8 replaces resistor Rf3 of Figure 4, and the resistors Rs3,RE3 of Figure 4 are connected to opposite ends of resistor R5, as illustrated in broken lines in Figure 8. Another circuit as shown in Figure 8 is then connected in a complementary manner, to replace the transistors 4,4a in Figure 4. A circuit as shown in Figure 8 can likewise replace the transistors 1,1a and 2,2a of Figure 4. In this case, the input terminal 21 of Figure 8 replaces the base of transistor 1a or 2a, and the output terminal 22 replaces the collector of transistor 1a or 2a.

Where supply rails are shown or mentioned in this specification or claims, it will be understood by those skilled in the art that any suitable supply voltages of any suitable polarity may be used as desired, including zero or "ground" potential.

25 In this specification, the verb "comprise" has its normal dictionary meaning, to denote non-exclusive inclusion. That is, use of the word "comprise" (or any of its derivatives) to include one feature or more, does not exclude the possibility of also including further features.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are
5 mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly
10 stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing
15 embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. An electronic amplifier comprising:
 - 5 a. voltage supply rails;
 - b. first and second electronic devices each having a respective conduction path and a respective control electrode for controlling conduction in said path, the conduction paths of
10 said first and second electronic devices being connected in series between said voltage supply rails and the control electrodes of said first and second electronic devices being arranged to receive an input signal to be amplified;
 - 15 c. an output node disposed between said conduction paths of said electronic devices, for connection to a load to be supplied with output current through said electronic devices; and
 - 20 d. first current compensation means arranged to supply current to said conduction path of said second electronic device when current is flowing through said first electronic device under conditions which would otherwise cause current flow through said conduction path of said second electronic device to cease.
- 25 2. An electronic amplifier according to claim 1, further comprising second current compensation means arranged to supply current to said conduction path of said first electronic device when current is flowing through said second electronic device under conditions which would

otherwise cause current flow through said conduction path of said first electronic device to cease.

- 5 3. An electronic amplifier according to claim 1 or 2, wherein the or each said current compensation means comprises a further electronic device arranged to sense the current flowing through said first or second electronic device and to supply current to said second or first electronic device in dependence upon the sensed current.
- 10 4. An electronic amplifier according to claim 1, 2 or 3, wherein each said electronic device comprises a transistor.
5. An electronic amplifier according to claim 4, wherein each said electronic device comprises a complementary pair of transistors.
- 15 6. An electronic amplifier according to claim 4 or 5, wherein each said transistor comprises a bipolar transistor.
7. An electronic amplifier according to claim 4 or 5, wherein each said
20 transistor comprises a field effect transistor.
8. An electronic amplifier according to claim 1, 2 or 3, wherein each said electronic device comprises a thermionic valve.
- 25 9. An electronic amplifier according to any of the preceding claims, being an audio amplifier.

10. An electronic amplifier according to any of claims 1 to 8, being an operational amplifier.
11. An electronic amplifier according to any of the preceding claims,
5 constructed as an integrated circuit.
12. An electronic amplifier substantially as hereinbefore described with reference to Figure 2, 3 or 4 of the accompanying drawings.
- 10 13. An electronic integrator comprising a first bipolar transistor and a current source connected in series, and a high-input-impedance device connected to said first bipolar transistor and current source, to form said integrator.
- 15 14. An electronic integrator according to claim 13, wherein said high-input-impedance device comprises a field effect transistor.
- 20 15. An electronic integrator according to claim 13 or 14, further comprising a current mirror connected to said current source.
- 25 16. An electronic integrator according to claim 15, wherein said current mirror comprises a second bipolar transistor having its collector-emitter path in series with that of said first bipolar transistor and a third bipolar transistor having its collector-emitter path in series with said current source and its base connected to the base of said second bipolar transistor, the collector-emitter paths of said second and third bipolar transistors being connected to a supply rail of higher potential than that supplying said high-input-impedance device.

17. An electronic integrator according to claim 16, further comprising a fourth bipolar transistor having its collector-emitter path connected between the base of the second bipolar transistor and said current source and a fifth bipolar transistor having its collector-emitter path connected in series with that of said third bipolar transistor and said current source.
18. An electronic integrator substantially as hereinbefore described with reference to Figure 6, 7 or 8 of the accompanying drawings.
19. An amplifier according to any of claims 1 to 12, incorporating an electronic integrator according to any of claims 13 to 18.

Amendments to the claims have been filed as follow

1. An electronic amplifier comprising:
 - a. voltage supply rails;
 - b. first and second electronic devices each having a respective conduction path and a respective control electrode for controlling conduction in said path, the conduction paths of said first and second electronic devices being connected in series between said voltage supply rails and the control electrodes of said first and second electronic devices being arranged to receive an input signal to be amplified;
 - c. an output node disposed between said conduction paths of said electronic devices, for connection to a load to be supplied with output current through said electronic devices; and
 - d. first current compensation means arranged to supply current to said conduction path of said second electronic device when current is flowing through said first electronic device under conditions which would otherwise cause current flow through said conduction path of said second electronic device to cease.
2. An electronic amplifier according to claim 1, further comprising second current compensation means arranged to supply current to said conduction path of said first electronic device when current is flowing through said second electronic device under conditions which would

otherwise cause current flow through said conduction path of said first electronic device to cease.

3. An electronic amplifier according to claim 1 or 2, wherein the or each
5 said current compensation means comprises a further electronic device arranged to sense the current flowing through said first or second electronic device and to supply current to said second or first electronic device in dependence upon the sensed current.
- 10 4. An electronic amplifier according to claim 1, 2 or 3, wherein each said electronic device comprises a transistor.
5. An electronic amplifier according to claim 4, wherein each said electronic device comprises a complementary pair of transistors.
- 15 6. An electronic amplifier according to claim 4 or 5, wherein each said transistor comprises a bipolar transistor.
7. An electronic amplifier according to claim 4 or 5, wherein each said
20 transistor comprises a field effect transistor.
8. An electronic amplifier according to claim 1, 2 or 3, wherein each said electronic device comprises a thermionic valve.
- 25 9. An electronic amplifier according to any of the preceding claims, being an audio amplifier.

10. An electronic amplifier according to any of claims 1 to 8, being an operational amplifier.
11. An electronic amplifier according to any of the preceding claims,
5 constructed as an integrated circuit.
12. An electronic amplifier according to any of the preceding claims,
wherein the or each said current compensation means comprises an
electronic integrator having a first bipolar transistor and a current source
10 connected in series, and a high-input-impedance device connected to said first
bipolar transistor and current source, to form said integrator.
13. An electronic amplifier according to claim 12, wherein said high-
input-impedance device comprises a field effect transistor.
15
14. An electronic amplifier according to claim 12 or 13, further
comprising a current mirror connected to said current source.
15. An electronic amplifier according to claim 14, wherein said current
20 mirror comprises a second bipolar transistor having its collector-emitter path
in series with that of said first bipolar transistor and a third bipolar
transistor having its collector-emitter path in series with said current source
and its base connected to the base of said second bipolar transistor, the
collector-emitter paths of said second and third bipolar transistors being
25 connected to a supply rail of higher potential than that supplying said high-
input-impedance device.

16. An electronic amplifier according to claim 15, further comprising a fourth bipolar transistor having its collector-emitter path connected between the base of said second bipolar transistor and said current source and a fifth bipolar transistor having its collector-emitter path connected in series with
5 that of said third bipolar transistor and said current source.

17. An electronic amplifier substantially as hereinbefore described with reference to Figure 2, 3 or 4 of the accompanying drawings.

10 18. An electronic amplifier substantially as hereinbefore described with reference to Figure 2, 3 or 4 of the accompanying drawings, as modified by Figure 6, 7 or 8 of the accompanying drawings.



The
Patent
Office

23

Applicati n No: GB 9721718.6
Claims searched: 1-12

Examiner: D. Midgley
Date of search: 16 January 1998

Patents Act 1977

Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H3W WUL,WVP

Int Cl (Ed.6): H03F 1/32,3/30

Other: ONLINE:WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 4274059 (VICTOR)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.



DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 986 165 A (TOKYO SHIBAURA ELECTRIC CO) 15 March 2000 (2000-03-15)	1-8, 18, 19, 24-28, 43-45	H02M1/12
Y	* column 2, line 10 - line 38; figure 2 *	20	
A	EP 0 920 116 A (TOKYO SHIBAURA ELECTRIC CO) 2 June 1999 (1999-06-02) * column 9, line 3 - line 10; figures 3, 7 *	2, 4, 5, 25-28, 43	
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